

# Probing nucleon interactions in QCD with EIC

C. Weiss (JLab), EIC User Group Meeting, ANL, 7-9 July, 2016



- Unifying perspective on  $ep$  and  $eA$  physics

Include large – intermediate – small  $x$

Adopt rest frame view: Longitudinal structure, nuclear physics intuition

Focus on dynamical system, not formal descriptors

- EIC measurements exploring nucleon interactions

$x > 0.3$       Gluon suppression in nuclei? Gluonic EMC effect?  
Modified nucleon structure

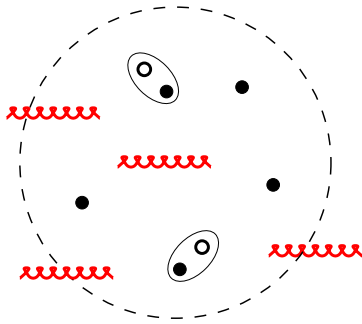
$x \sim 0.1$       Sea quark and gluon enhancement? Charge–flavor separation?  
QCD structure of exchange interactions

$x < 0.01$       Emergence of collective gluon fields – shadowing, saturation  
High-energy nucleon interactions, diffraction

*How do nuclei emerge from the microscopic theory of strong interactions?*

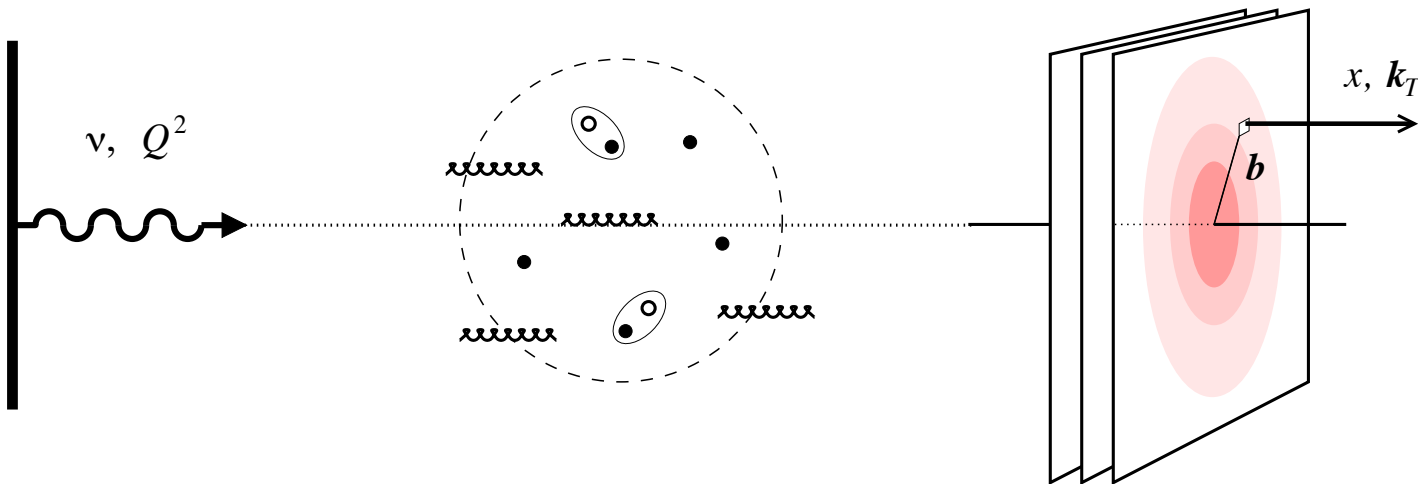
# Nucleon in QCD: Dynamical system

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- Relativistic: Particles appear/disappear, momenta  $\gg$  masses, shape frame-dependent
- Quantum-mechanical: Fluctuations, superposition of configurations
- Strongly coupled: Symmetry breaking, mass generation, effective DoF

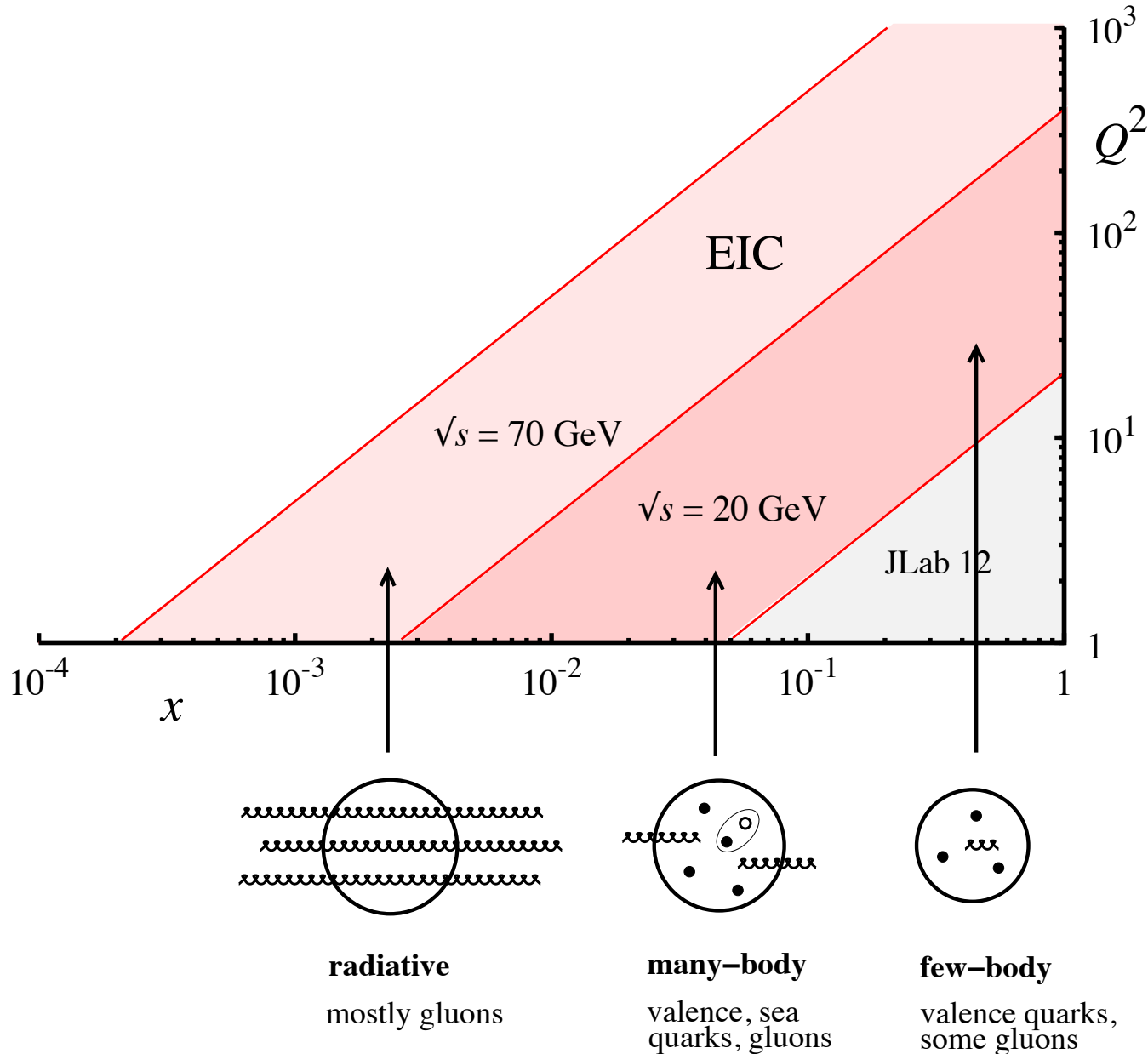
} Uniquely challenging!



- High-energy EM scattering takes snapshot
- Physical characteristics: Particle densities, spatial distributions, orbital motion, correlations
- Energy and momentum transfer select configurations probed

# Nucleon in QCD: Landscape

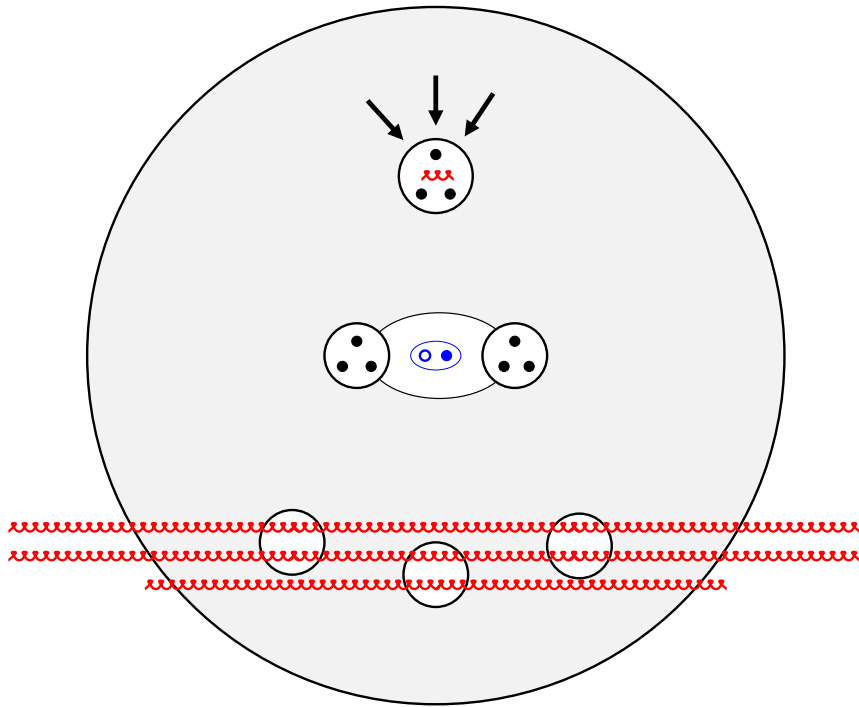
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- Probe different components
- Learn about dynamics
  - Sea quarks  $\leftrightarrow$  chiral symmetry breaking
  - Origin of non-pert gluons, polarization?
- EIC nucleon structure program  
INT report, this meeting
- What about nucleon interactions?  
Next step!

# Nucleon interactions: $A \neq \sum N$

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$x > 0.3$  “EMC effect”  
Modified single-nucleon structure?  
Non-nucleonic degrees of freedom?

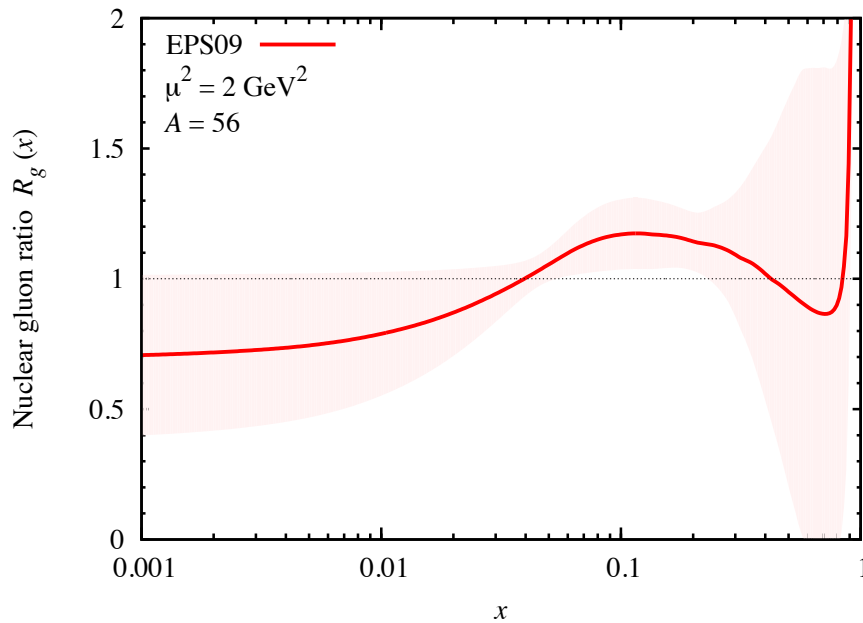
$x \sim 0.1$  “Antishadowing”  
QCD structure of pairwise  $NN$   
interaction, exchange mechanisms

$x < 0.01$  “Shadowing”  
QM interference,  
collective gluon fields

- Nuclear modification of quark/gluon structure reveals QCD origin of nucleon interactions
- Distinct dynamical mechanisms in different regions of  $x$
- Alternative viewpoint: Coherence length of DIS process  $l_{\text{coh}} \sim 1/(M_N x)$

# EIC: Nuclear gluons at $x > 0.3$

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- Are gluons suppressed at  $x > 0.3$ ?

Cf. Valence quarks: EMC effect, JLab 6 & 12 GeV

Modification of nucleon's gluonic structure due to interactions?

Non-nucleonic DOF in nucleus?

- Poorly known: Global fits
- EIC: Nuclear gluons from inclusive  $F_{2A}$ ,  $F_{LA}$  and DGLAP evolution

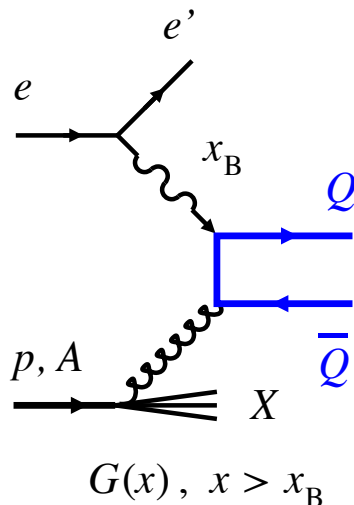
Limited sensitivity to large  $x$

- EIC: Nuclear gluons with heavy quarks

Direct probe, unique sensitivity

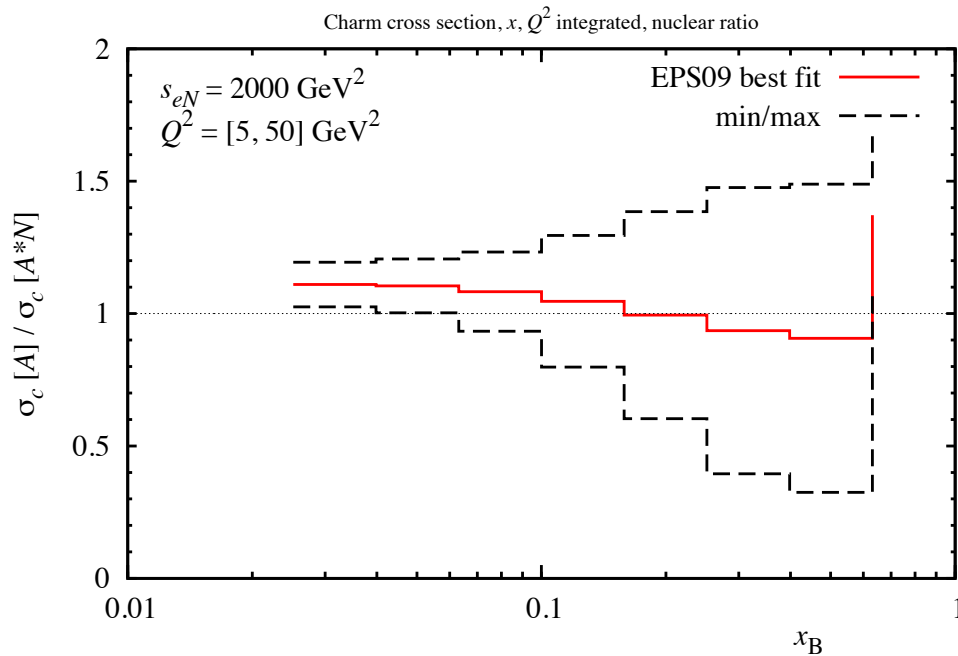
Used in HERA  $ep$  at  $x_B < 0.01$

EIC enables  $eA$  at large  $x_B$

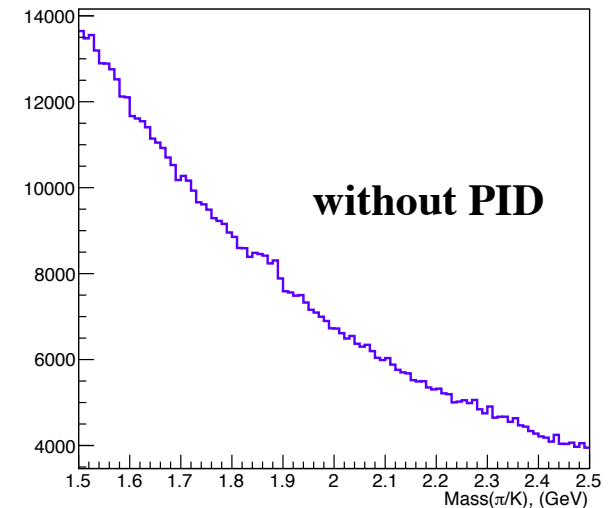
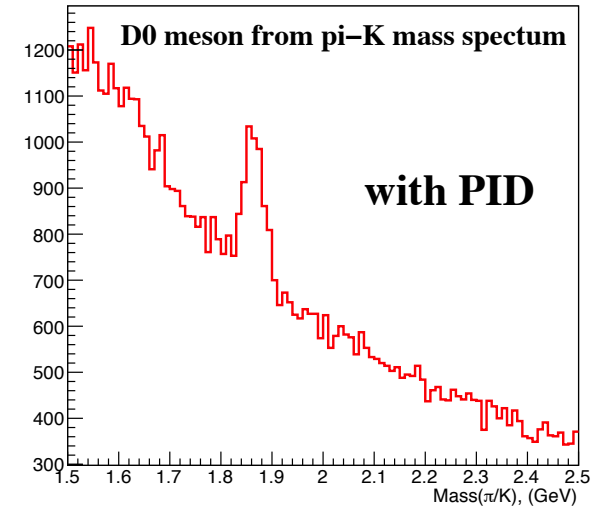


# EIC: Nuclear gluons at $x > 0.3$

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- Excellent sensitivity to large- $x$  gluons ( $x > x_B$ )
- Charm rates  $\sim 10^5/\text{bin}$  at  $x_B \sim 0.1$  with  $10^{34}$  lumi
- Medium-energy EIC ideal for large- $x$  charm detection
- Aim for charm reconstruction with  $\sim \text{few } \%$  efficiency using next-generation PID capabilities

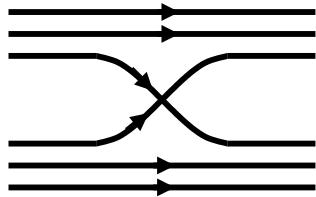


Yu. Furletova

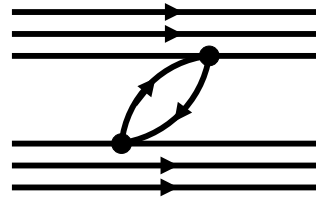
JLab FY16 LDRD project  
[https://wiki.jlab.org/nuclear\\_gluons/](https://wiki.jlab.org/nuclear_gluons/)

# EIC: Nuclear quarks and antiquarks at $x \sim 0.1$

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quark exchange

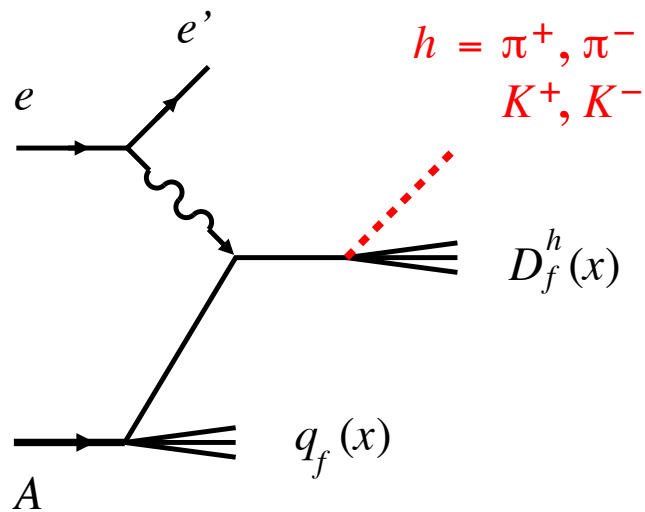


meson exchange

- Are quarks and/or antiquarks in nuclei enhanced at  $x \sim 0.1$ ?

$NN$  interaction by quark or meson exchange?

Flavor decomposition?



- EIC: Charge-flavor separation with semi-inclusive  $\pi, K$

Extensive experience with  $ep$

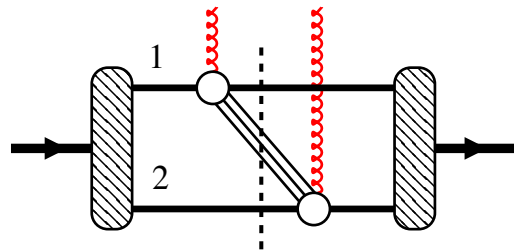
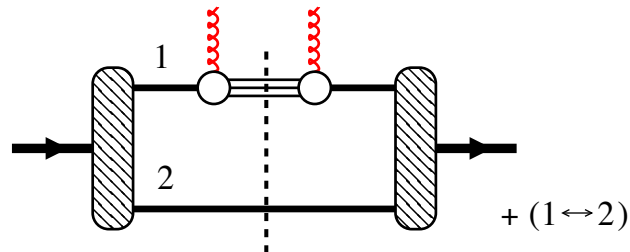
$eA$ : Separate initial-state modifications from nuclear final-state interactions using  $A$ -dependence

- Simulations in progress

Zhihong Ye, D. Higinbotham, CW

# EIC: Collective gluon fields at $x < 0.01$

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- How do collective gluon fields build up in nucleus at  $x \ll 0.1$ ?

High-energy  $NN$  interactions involving color

- Shadowing: QM interference of gluons from different nucleons

Enabled by diffractive interactions

Suppresses gluons at  $x \ll 0.1$

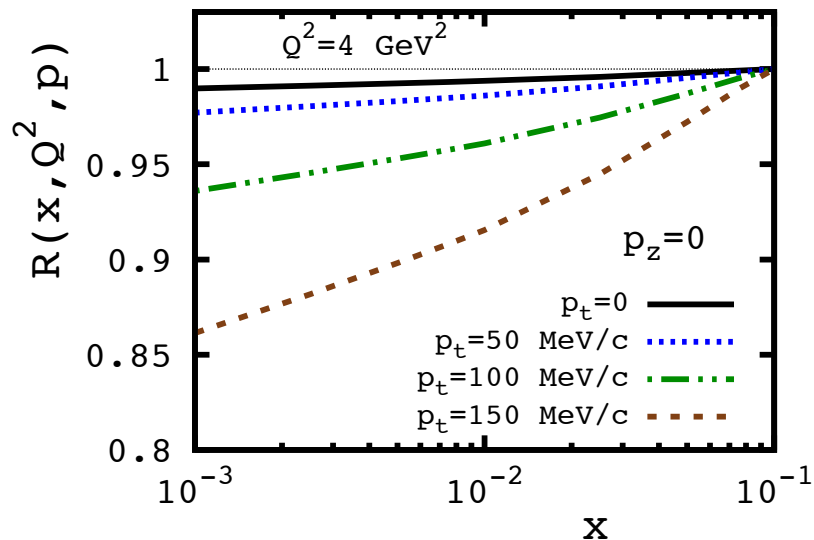
Seen in ultraperipheral  $AA$  at LHC ALICE

Determines approach to saturation

- EIC: Tagged deuteron DIS as laboratory  
 $e + D \rightarrow e' + N(p) + X$

Large shadowing effects predicted

QM interference directly visible





- Unifying perspective on  $ep$  and  $eA$  physics with EIC
- Nuclear quark-gluon structure reveals aspects of  $NN$  interactions in QCD at different distances and energies

$x > 0.3$       Modified single-nucleon structure

$x \sim 0.1$        $NN$  interactions at average distances  $\sim 1\text{--}2$  fm

$x < 0.01$       High-energy interactions producing collective gluon fields

- Other EIC processes probing  $NN$  interactions

Tagged EMC effect and short-range  $NN$  correlations

→ Talks Ch. Hyde, Or Hen

High-energy deuteron breakup and hidden color components

Miller, Sievert, Venugopalan 16